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PHYSICO-CHEMICAL AND ENERGY PROPERTIES OF BIOMASS BRIQUETTES COMPOSED FROM DAIRY COW FECES AND COFFEE GROUND WITH TAPIOCA FLOUR ADDITION

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Abstract

Cow feces are the byproduct of livestock digestive process, while coffee grounds are the remnants of coffee brewing. Both are organic materials containing fixed carbon that can be utilized as fuel. The purpose of this study was to determine the effect of adding coffee grounds to dairy cow feces briquettes production process, on their physical properties (color, texture, density), chemical properties (moisture content, ash content, volatile matter, and fixed carbon), and energy value (calorific value, temperature, flame duration). This research method was experimental, with four treatments: P1 (100 g dairy cow feces + 20 g coffee grounds), P2 (100 g dairy cow feces + 40 g coffee grounds), P3 (100 g dairy cow feces + 60 g coffee grounds), P4 (100 g dairy cow feces + 80 g coffee grounds). Each treatment was repeated five times. Data were statistically analyzed with ANOVA at a 5% significance level, followed by the Duncan test for further comparison. The results showed that adding coffee grounds significantly affected ($p<0.05$) the briquette's physical properties (density), chemical properties (moisture content, ash content, volatile substances, fixed carbon), and energy value (calorific value, temperature, and flame duration). The addition of 80 grams of coffee grounds (P4) produced the best performing dairy cow feces briquettes, with a moisture content of 6.94%, ash content of 25.47%, volatile matter of 18.58%, fixed carbon of 49.02%, calorific value of 3717 cal/gr, and burning temperature of 463°C.

Keywords: briquettes, dairy cow feces, coffee grounds, calorific value

SIFAT FISIKO-KIMIA DAN NILAI ENERGI BRIKET BIOMASSA FESES SAPI PERAH DAN AMPAS KOPI DENGAN PENAMBAHAN TEPUNG TAPIOKA

Abstrak

Feses sapi merupakan hasil sampingan dari proses pencernaan ternak, sedangkan ampas kopi merupakan bahan sisa penyeduhan kopi. Feses sapi dan ampas kopi merupakan bahan organik yang mengandung karbon tetap yang dapat dimanfaatkan sebagai bahan bakar. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh penambahan ampas kopi pada proses pembuatan briket feses sapi perah terhadap sifat fisik (warna, tekstur, kerapatan), sifat kimia (kadar air, kadar abu, zat mudah menguap, dan karbon terikat), dan nilai energi (nilai kalor, temperatur, lama penyalaan). Metode penelitian ini bersifat eksperimental dengan empat perlakuan: P1 (100 g feses sapi perah + 20 g ampas kopi), P2 (100 g feses sapi perah + 40 g ampas kopi), P3 (100 g feses sapi perah + 60 g ampas kopi), P4 (100 g feses sapi perah + 80 g ampas kopi). Setiap perlakuan diulang sebanyak lima kali. Data dianalisis secara statistik dengan ANOVA pada tingkat signifikansi 5%, diikuti dengan uji Duncan untuk perbandingan lebih lanjut. Hasil penelitian menunjukkan bahwa penambahan ampas kopi berpengaruh nyata ($p<0,05$) terhadap sifat fisik (kerapatan), sifat kimia (kadar air, kadar abu, zat mudah menguap, karbon tetap), dan nilai energi (nilai kalor, temperatur, dan lama penyalaan). Penambahan 80gram ampas kopi (P4) menghasilkan briket feses sapi perah dengan performa terbaik, dengan kadar air 6,94%, kadar abu 25,47%, zat mudah menguap 18,58%, karbon terikat 49,02%, nilai kalor 3717 kal/gr, dan temperatur pembakaran 463°C.

Kata kunci: briket, feses sapi perah, ampas kopi, nilai kalor

INTRODUCTION

To reduce agricultural waste and improve energy sustainability, this research examines the potential for utilizing dairy cow feces as an environmentally friendly briquette raw material. The use of dairy cow feces is based on population data of leading commodities in the livestock business in Indonesia. Quoting from Indonesian Central Bureau of Statistic (2024), cow's milk production in West Java Province in 2023 reached 268,467 tons. The largest cow's milk-producing region is West Bandung, with 95,830 tons, followed by Bandung and Garut, with 60,514 tons and 26,947 tons, respectively. The three regions have farmer cooperatives engaged in the dairy milk production sector, namely Koperasi Peternak Sapi Bandung Utara (KPSBU), Koperasi Peternak Bandung Selatan (KPBS), and Koperasi Peternak Garut Selatan (KPGS). The more the livestock business develops, the more waste it can generate, including feces. This is related to environmental pollution if the waste generated from livestock is not managed appropriately. Fitriati et al. (2021) state that a cow can produce 10 - 15 kg/hr. If it is assumed that the feces produced by a cow is 10 kg/hr, then an increase in the dairy cows' population will make a massive amount of feces.

Dairy cow waste can be used as sustainable fuel in briquettes, providing an alternative to wood charcoal for cooking. However, the energy produced by dairy cow feces is relatively weak compared to other energy sources. A fuel's energy is associated with its calorific value, which is influenced moisture content, ash content, volatile matter, and fixed carbon (Saputro & Widayat, 2016). The higher the fixed carbon in a material, the higher the heating value produced (Putri & Andasuryani, 2017).

Dairy cow feces are biomass with a hemicellulose content of 18.6%, cellulose of 25.2%, lignin of 20.2%, nitrogen of 1.67%, phosphate of 1.11%, and potassium of 0.56% (Windyasmara et al., 2012). This biomass is utilized as an environmentally friendly and sustainable alternative fuel. However, the energy generated from using dairy cow feces in briquettes still needs to be developed to approach the energy produced by other fuels.

Based on SNI 01-6235-2000, the requirements for briquettes are a maximum moisture content of 8%, maximum volatile matter of 15%, maximum ash content of 8%, and minimum calorific value of 5000 cal/g. Briquettes' moisture and ash content affect their calorific value, combustion process, and quality. Briquettes with more than 8% moisture content are difficult to ignite, as high moisture hampers the combustion process. The heat generated becomes ineffective because the heat is used to evaporate the water in the briquettes (Chusniyah et al., 2022). Volatile matter in briquettes affects the smoke produced during the combustion process. The highly volatile matter will produce more smoke (Rahmadani et al., 2017).

Research conducted by Suharto et al. (2018) showed that treating cow feces briquettes with various adhesive levels resulted in a calorific value below 4000 cal/gr. The results of the study by Iftikhar et al. (2019) indicated that using cow dung in large quantities increased the ash content and volatile matter, decreasing the briquettes' calorific value. Other biomass sources are necessary to produce a better-quality briquette.

The material added to produce good briquette quality is coffee grounds. Coffee grounds are the residue of coffee brewing from grinding coffee beans. Coffee grounds contain 33.57% lignocellulose, 47.90% hemicellulose, and 18.52% lignin (Indah & Fachreza, 2020). The dominant addition of coffee grounds powder to paper waste, according to the research by Kamal (2022), produced a high calorific value of 5605 cal/gr. Yoisangadji & Pohan (2022) found that a mixture of 20 g of coffee grounds with 10 grams of pine fruit produced briquettes with a calorific value of 7453 cal/g. Coffee grounds have a low ash content of 0.90% (Colantoni et al., 2021).

The greater quantity of coffee grounds added to dairy cow feces briquettes is expected to produce briquettes with low moisture content, ash content, and volatile substances and add total fixed carbon that can increase the heating value. The availability of these two briquette materials is relatively abundant and categorized as waste. Utilizing dairy cow feces and coffee grounds reduces the environmental burden and can become sustainable, environmentally friendly energy. Based on the above, studying the physicochemical and energy quality of briquettes made with dairy cow feces and variations in adding coffee grounds is essential.

MATERIALS AND METHODS

Material

The equipment used in this research was a pyrolysis drum, drying oven, stove, gas, gas, size 60 net, basin, stirrer, scales, petri dish, pot, furnace, oven, tray, spray bottle, baking sheet, thermometer, stopwatch, and briquette printer. The materials used were dairy cow feces obtained from Padjadjaran University dairy cattle barn, coffee grounds obtained from Layung coffee shop, tapioca flour branded Cap Jangkar, and water.

Methods

Preparation of Briquette Raw Materials

The material preparation process included procuring charcoal from dairy cow feces, coffee grounds, and tapioca starch. Dairy cow feces were dried in an oven for 15 hours at 60°C, and coffee grounds in a wet state were dried using a drying oven for 4 hours at 110°C (Ngadiyah & Haryanto, 2019). The dried dairy cow feces and coffee grounds were then pyrolyzed into charcoal. After they became charcoal, they were sieved with a 60-mesh sieve.

Briquette Production Process

Briquettes were made by mixing cow feces, charcoal, and coffee grounds according to the treatment. Tapioca startch (5% of the total weight of the treatment) was dissolved tapioca in water at a 1:3 ratio and heated on a pan until thickened. The mixture dough was then stirred and molded with a simple briquette press into square cylinder measuring 3.6 cm x 3.6 cm. The molded briquettes were sun-dried for 3 hours, followed by oven-drying at 60°C for 24 hours until they reached 6% moisture content.

Briquette Quality Analysis

The dried briquettes were analyzed for physical, chemical, and energy value. Physical properties such as color and texture were described according to the state of the sample. At the same time, the density of the briquettes was determined by measuring their dimensions and weight. The temperature was measured using a thermal gun; heat was measured with a calorimeter bomb and flame duration was measured using a stopwatch. The analysis was conducted at the Laboratory of Ruminant Animal Nutrition and Animal Food Chemistry, Faculty of Animal Science, Padjadjaran University. The moisture content (%), ash content (%), volatile matter (%), and fixed carbon (%) of each treatment were measured by the proximate analysis method (Association of Official Analytical Chemist, 2005).

- Moisture content, Eq. (1):

$$MC\ (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where:
W1 = weight of cup (g)
W2 = weight of cup + sample (g)
W3 = weight of cup + sample after drying (g)

- Ash content, Eq. (2):

$$Ash\ (\%) = \frac{W_2}{W_1} \times 100$$

where:
W1 = the weight of the sample (g)
W2 = weight of remaining ash (g)

- Volatile matter, Eq. (3):

$$VM\ (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where:
W1 = weight of empty cup (g)
W2 = weight of cup + fine dry sample (g)
W3 = weight of cup + sample after heating (g)

- Fixed carbon, Eq. (4):

FC (%)=100 – (MC + VM + Ash)

Experimental Design and Data Analysis

The research method used was an experimental method using a completely randomized design with four treatments: P1 (100 g dairy cow feces + 20 g coffee grounds + 6 g tapioca), P2 (100 g dairy cow feces + 40 g coffee grounds + 7 g tapioca), P3 (100 g dairy cow feces + 60 g coffee grounds + 8 g tapioca) and P4 (100 g dairy cow feces + 80 g coffee grounds + 9 g tapioca). Each treatments were replicated five times. The tapioca adhesive was 5% of the briquette material. The data obtained were analyzed using variance analysis from a one-way randomized design with the SPSS version 25 application with a probability value of less than 5%. Data with significant differences will be tested further with Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Physical Properties

The physical properties observed in this study include color, texture, and density. Table 1 shows the effect of adding coffee grounds to cow feces briquettes on these properties.

Table 1. Physical Properties of Cow Feces and Coffee Grounds Blended Briquettes

Physical properties	Treatment			
	P_1	P_2	P_3	P_4
Color	Black	Black	Black	Black
Texture	Rough - dense	Rough - dense	Rough - crumbs	Rough - crumbs
Density (g/cm^3)	0.50±0.04^b	0.51±0.03^b	0.44±0.00^a	0.44±0.01^a

Note: Different lowercase letters toward the column indicate significant differences

Color

The color of the briquettes is identical to black—resulting from the charring process of the raw materials of the briquette. In the charring process, a chemical reaction occurs between oxygen and elements found in cow feces and coffee grounds. This chemical reaction causes changes in the material's molecular structure, resulting in black carbon compounds. Dried dairy cow feces are light brown, while dried coffee grounds are darker brown. Good charring will produce black material, while incomplete charring will leave the bright brown color of dairy cow feces. If the resulting color is gray, it is not charring but complete combustion. Biomass that has been pyrolyzed at 325°C - 375°C produces black charcoal. (Saparudin et al., 2015).

Texture

Each treatments in this study produced a rough texture, caused by the coarse particles that made up the briquettes. The charcoal powder used in the briquettes was sieved with a 60-mesh sieve. A smaller sieve size would produce finer charcoal powder, and would bind better with the adhesive. The P1 and P2 treatments had a dense texture, due to the dominating concentration of dairy feces. The P3 and P4 treatments resulted in crumbly briquettes, due to the increasing concentration of charcoal in the coffee grounds mixture.

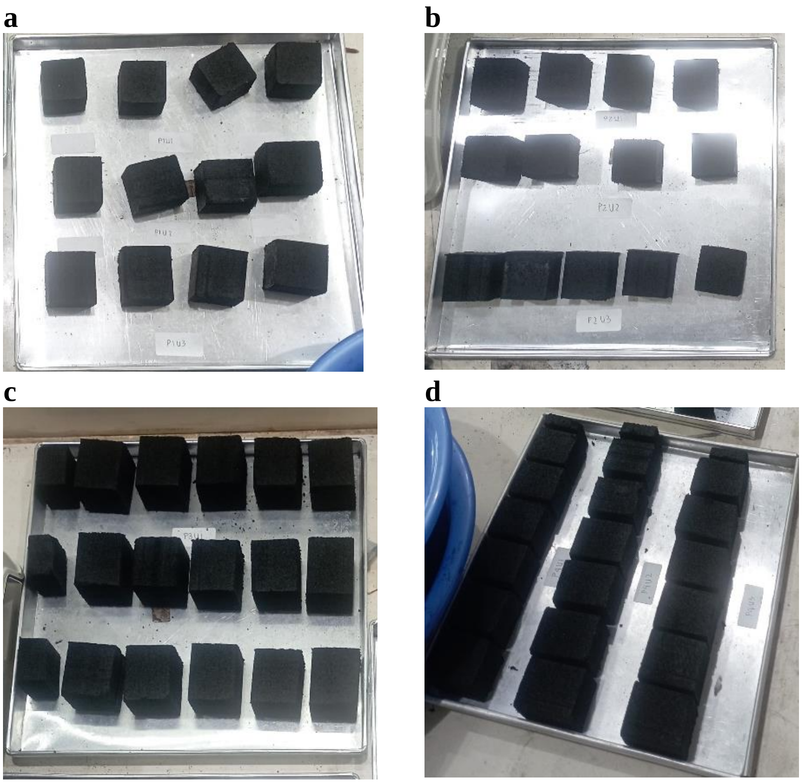

Figure 1. Cow Feces and Coffee Grounds Briquettes Color;
(a) Briquettes treated with P1, (b) Briquettes treated with P2,
(c) Briquettes treated with P3, (d) Briquettes treated with P4

The size of coffee grounds varied according to the needs of coffee business actors, ranging from coarse to super fine. In this study, a fine coffee grounds measuring 200 - 400 µm was used. Coffee grounds have a larger particle size than cow feces. This aligns with the opinion of Muliawan et al. (2020), that good-quality briquettes should have a smooth, sturdy, and unbreakable texture.

Density

Density refers to the mass of an object or substance per unit volume (g/cm^3), calculated by dividing the weight by the object's volume. The briquette density measurements are presented in Table 1, with values ranging from 0.44 - 0.51 g/cm^3 across all treatments. Analysis results indicate that adding coffee grounds to the mixture of cow feces briquettes significantly affects density between treatments.

A good briquette is expected to have a high density as it affects the moisture content and temperature produced. The highest density was observed in P2 (40 grams of coffee grounds), with a density of 0.51 g/cm^3. In comparison, the lowest density was found in P3 and P4 (60 grams and 80 grams of coffee grounds), measuring 0.44 g/cm^3. This decrease in density was due to the higher addition of coffee grounds in the briquette mixture. Coffee grounds have larger particle sizes than dairy cow feces charcoal. Both cow feces charcoal and coffee grounds charcoal were filtered using a 60-mesh sieve, but the coffee grounds charcoal that passes the 60 mesh sieve was still more significant than the particles of cow feces charcoal.

Briquette molding was done manually using a simple non-machine mold. This was related to the pressure used to print briquettes, which ranged from 136.54 to 142.80 psi. Low density was inversely proportional to briquette volume, meaning that as the proportion of coffee grounds increased, the dimensions or volume of the briquettes also increased. This findings align with the opinion of Hutagaol et al. (2015) and Jaswella et al. (2022), that the briquettes density is influenced by the particle size of raw materials and pressure during molding.

Chemical Properties

The chemical properties tested in this study included moisture content, ash content, volatile matter, and fixed carbon. The effect of adding coffee grounds to cow feces briquettes on chemical properties is shown in Table. 2

Moisture Content

The addition of different amounts of coffee grounds in each treatment significantly affected the water content of cow feces briquettes. After further testing, the addition of 80 grams (P4) significantly affected the 20 grams (P1), 40 grams (P2), and 60 grams (P3) treatments. Meanwhile, the P3 treatment had no significant effect on P1 and P2.

Briquettes are composed of dairy cow feces and coffee grounds roasted first. Charcoal has hygroscopic properties, namely the ability of a substance to absorb water molecules. The water content in the briquettes increased as the amount of coffee grounds increased in each treatment. Coffee grounds charcoal, as active carbon, can absorb or is known as an adsorbent. The hygroscopic nature of charcoal is one of the factors causing the increase in water content in charcoal (Sahara et al., 2017). Coffee grounds charcoal has a broader particle size than cow feces charcoal. This large surface absorbs more water molecules than substances with a small surface. This follows Rahman et al. (2021) Increasing the area of the adsorbent can absorb more pollutants.

Table 2. Chemical Properties of Cow Feces and Coffee Grounds Blended Briquettes

Chemical properties	Treatment			
	P_1	**P_2**	**P_3**	**P_4**
Moisture content (%)	6.52±0.10^a	6.67±0.07^b	6.64±0.23^b	6.94±0.13^c
Ash content (%)	37.18±1.52^d	32.79±0.79^c	28.54±0.76^b	25.47±0.08^a
Volatile matter (%)	30.36±1.80^d	26.04±0.78^c	22.17±0.78^b	18.58±0.22^a
Fixed carbon (%)	25.726±3.06^a	39.99±1.90^b	42.92±1.65^b	49.01±0.14^d

Note: Different lowercase letters toward the column indicate significant differences

The increase in water content aligns with the emergence of smoke when the briquettes are burned. Briquettes treated with 60 grams of coffee grounds (P3) and 80 grams of coffee grounds (P4) produced quite a lot of white smoke during the combustion process. This follows Putri & Andasuryani (2017) The water content is too high in briquettes, producing a lot of burning smoke. The expected moisture content value follows SNI 01-6235-2000 concerning wood charcoal briquettes, namely ≤ 8%. Attention to the drying time of the briquettes can also minimize their moisture content. The longer the drying time, the lower the moisture content of the briquettes.

Ash Content

The results showed that adding coffee grounds significantly affected ash content ($P<0.05$). The more coffee grounds are added to the briquette mixture, the less ash content will be reduced. Each treatment has a significantly significant effect on the other. P1 obtained the highest ash content with 20 grams of coffee grounds, 37.18%. In comparison, the lowest ash content was obtained by adding 80% of coffee grounds, namely 25.47%. This value still does not meet the ash content standards set by SNI 01-6235-2000, namely ≤ 8%. The decrease in ash content with the size of the treatment is thought to be caused by the decreasing concentration of dairy cow feces.

The highest ash content was found in treatment P1 (100 grams of cow feces + 20 grams of coffee grounds). In contrast, the ash content decreased with increasing addition of coffee grounds to the treatment. The more coffee grounds added, the lower the concentration of cow feces in each printed briquette cube and vice versa. The mineral content is thought to come from the feces of the dairy cows used. This is supported by research conducted by Garg Kumar and Mudgal Vishal (2007), which found mineral nutrients such as calcium, phosphorus, zinc, copper, iron, and manganese in the feces of Desi cows and crossbred cows.

The ash content in the briquettes shows the inorganic substances left behind after combustion, such as silica and minerals. These remaining minerals include Al_2O_3 (aluminum oxide), SiO_2 (silicon dioxide), CaO (calcium oxide), and Fe_2O_3 (ferric oxide), which cannot be oxidized by oxygen (Ristianingsih et al., 2015)

The carbohydrate content in coffee grounds decreases the ash content as the concentration of coffee grounds increases. Carbohydrate compounds can reduce the mineral content of biomass in thermochemical processes, which leads to an increase in calorific value (Dyah & Yossy, 2022; Soleimani et al., 2017).

The ash content of briquettes is expected to be low, as it improves combustion efficiency. Ash content in briquettes can be minimized by selecting raw materials with low mineral content, optimizing the combustion temperature, and determining the suitable adhesive and drying technique level.

Volatile Matter

The analysis showed a decrease in volatile substances as the concentration of coffee grounds charcoal increased. The volatile matter values of each treatment were sequentially 30.36% (P1), 26.04% (P2), 22.18% (P3), and 18.58% (P4). The lowest volatile matter value was observed in P4 (80 grams of coffee grounds), while the highest was found in P1 (20 grams of coffee grounds).

Volatile matter determines the amount of smoke produced during combustion. High levels of volatile substances indicate the presence of volatile chemical components during the combustion process (Iskandar et al., 2019). The high volatile matter was thought to be caused by the lower charcoal concentration of dairy cow feces in the P4 treatment.

The carbonization process of the briquette's raw material into activated carbon influences its volatile matter content. The carbonization process of briquette materials is related to increasing the temperature and combustion time. Higher carbonization temperatures break down non-carbon compounds such as water and gas (Ratnani et al., 2019), thereby reducing volatile substances and resulting in higher carbon content.

Fixed Carbon

Apart from the water, ash, and volatile matter fractions, the carbon fraction (fixed carbon) is also contained in briquettes. The results of testing the carbon content of each treatment are presented in Table 2. The lowest fixed carbon was obtained in the treatment with

20 grams of coffee grounds (P1), namely 25.72%. The highest fixed carbon was obtained in the treatment with 80 grams of coffee grounds (P4), namely 49.01%.

The carbon element in briquettes acts as a source of combustion energy. When briquettes are burned, their carbon will burn and release heat energy that can be used as fuel. The carbon element in briquettes is expected to be in large quantities because the higher the carbon value, the higher the calorific value contained in the briquettes.

Treatment P4 has a high carbon content due to the high content of coffee grounds. Coffee grounds are plant residues with a high carbon content. Briquette carbon comes from cellulosic elements in cow feces and coffee grounds. This aligns with Windyasmara et al. (2012), who states that dairy cow feces have a hemicellulose content of 18.6%, 25.2% cellulose, and 20.2% lignin. According to (Indah & Fachreza, 2020)Coffee grounds contain 33.57% lignocellulose, 47.90% hemicellulose, and 18.52% lignin. Coffee grounds have a higher lignocellulose value than cow feces. Lignocellulose is a component that makes up cell walls in plants, so the amount is higher than the lignocellulose found in dairy cow feces.

This is also supported by research conducted by Sampathkumar et al. (2019), which found that feces made from dairy cow feces have a smaller fixed carbon value than briquettes made from agricultural waste. In that study, the small value of bound carbon was followed by a high value of volatile matter. Similarly, in this study, briquettes with higher amounts of cow feces had smaller bound carbon values and higher volatile matter values than the other treatments. The addition of coffee grounds to the briquette mixture succeeded in increasing the fixed carbon contained in it.

Energy Value

The energy values tested in this research include heating value, temperature, and flame duration. Table 3 presents the effect of adding coffee grounds to cow feces briquettes on energy value.

Calorific Value

The calorific values of briquettes obtained in this study are ranging from 2744 – 3723 cal/g, as presented in Table 3. The highest calorific value was recorded in treatment P4 (100 gr of cow feces + 80 gr of coffee grounds), at 3717 cal/g, while the lowest calorific value was in treatment P1 (100 gr of cow feces + 20 gr of coffee grounds) at 2748 cal/g. Calor is the heat energy from fuel through a complete combustion reaction (Aljarwi et al., 2020). The ash content, volatile matter, and carbon content influence the calorific value. The ash content and volatile matter in P4 have low values, followed by high carbon content.

The higher calorific value is due to the amount of coffee grounds added. Coffee grounds play an essential role in the briquettes' fixed carbon. The calorific value is consistent with the results of testing the fixed carbon in the briquettes. Treatment P4 has the highest carbon content and a high heating value. Research by Jain et al. (2020) The calorific value measurements of briquettes made from cow feces and sawdust were compared. As a result, cow feces briquettes produced a calorific value of 3066 cal/g, while sawdust briquettes produced a calorific value of 4380 cal/g. The use of agricultural waste or plant residues proved to help increase the calorific value of briquettes.

Table 3. Energy Value of Cow Feces and Coffee Grounds Blended Briquettes

Energy Value	Treatment			
	P_1	**P_2**	**P_3**	**P_4**
Calorific value (cal/g)	2748 ± 57.84^{a}	3172 ± 57.76^{b}	3519 ± 71.90^{c}	3717 ± 98.81^{d}
Temperature (°C)	422 ± 12.55^{a}	451 ± 9.83^{b}	444 ± 29.95^{ab}	463 ± 10.21^{b}
Flame duration (min)	57 ± 0.00^{a}	69 ± 6.61^{c}	60 ± 3.93^{ab}	64 ± 1.64^{bc}

Note: Different lowercase letters toward the column indicate significant differences

The calorific value also aligns with the results of testing the briquettes' ash content and volatile matter: the smaller the briquettes' ash content and volatile matter, the higher the calorific value. The ash and volatile matter values decrease with the increase of coffee grounds, causing the calorific value to increase.

The expected calorific value of a fuel is high to produce good-quality energy. However, the calorific value obtained is still below the standard set by SNI 01-6235-2000, namely a minimum of 5000 cal/gr. This test proves that dairy cow feces waste and coffee grounds have the potential to be used as sustainable alternative energies.

Temperature

The temperatures produced by each treatment were 422°C, 451°C, 444°C and 463°C for P1, P2, P3, and P4, respectively. The analysis results show that treatment P1 significantly differed from treatments P2 and P4. The lowest temperature obtained by treatment P1 (100 grams of cow feces + 20 grams of coffee grounds) was 422°C. In comparison, the highest temperature obtained by treatment P4 (100 grams of cow feces + 80 grams of coffee grounds) was 463°C. High temperature is thought to be caused by the small density value in P4 (0.437 g/cm^3). A small density value affects the resulting temperature. A small density will make it easier for airflow to enter so that the burning rate of the briquettes is faster. In line with Almu et al. (2014), high airflow speed will increase combustion temperature.

The temperature produced by briquettes was still relatively small when compared to LPG. The amount of carbon elements in each fuel causes low temperatures. The carbon elements of briquettes are composed of methane (CH_4) and hemicellulose ($C_5H_{10}O_5$). In contrast, LPG is composed of propane gas (C_3H_8), butane (C_4H_{10}), and propylene (C_3H_6). The combined gases that form LPG have double bonds that are more reactive so that fire can easily catch fire (Abidin, 2010). This causes LPG to have a faster burning rate and higher temperature than briquettes.

Flame Duration

The flame duration of the briquettes for each treatment sample ranged from 57 to 69 minutes. The Duncan Advanced Test showed that P2 (60 grams of coffee grounds) had a significantly longer burning time (69 minutes) than P1. The flame duration of the briquettes is not the same as the burning rate. The burning rate and flame duration are inversely proportional; the higher the burning rate, the shorter the burning time, and vice versa. Good briquettes have a low burning rate or long burning time.

Several factors influence the flame duration, including water content, ash content, and briquette density. High-density briquettes produce a low combustion rate and a long flame duration because it is difficult for oxygen to enter the briquette gaps. Based on Table 3, treatment P2 had the highest density value compared to other treatments, producing a longer flame time than other treatments. Therefore, high-density briquettes are preferable for optimal performance, as they ensure a longer-lasting flame and more efficient energy output.

CONCLUSIONS

The addition of 80 grams of coffee grounds (P4) resulted in the best-performing dairy cow feces briquettes, with a moisture content of 6.94%, ash content of 25.47%, volatile matter of 18.58%, fixed carbon of 49.02%, calorific value of 3,717 cal/gr, and burning temperature of 463°C. Adding coffee improves the quality of dairy cow feces briquettes in terms of volatile matter, carbon value, and briquette heat. Therefore, coffee grounds and dairy cow feces have the potential to be converted into renewable energy sources and sustainable waste management applications.

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